3726

91012

ASTIA FILE COPY

TECH. NOTE
I.A.P.1050

TECH. NOTE
I.A.P.1050

SECRET - DISCREET

ROYAL AIRCRAFT ESTABLISHMENT

F A R N B O R O U G H , H A N T S

TECHNICAL NOTE No: I.A.P.1050

FLIGHT INSTRUMENT SYSTEMS

REPORT ON VISIT TO U.S.A.

by

C.N.JAQUES, B.Sc., F.R.Ae.S.,

A. STRATTON, M.Sc., A.M.I.E.E., F.Inst.P.

and Sqn.Ldr.J.C.T.DOWNEY, D.F.C., A.F.C.

FC

SEPTEMBER, 1955

M I N I S T R Y O F S U P P L Y

SECRET - DISCREET

U.D.C. No. 06.076(73) : 629.1305

Technical Note No. I.A.P. 1050

September, 1955

ROYAL AIRCRAFT ESTABLISHMENT, FARNBOROUGH

Flight Instrument Systems

Report on Visit to U.S.A.

by

C. N. Jaques, B.Sc., F.R.Ae.S.
A. Stratton, M.Sc., A.M.I.E.E., F.Inst.P.
S/Ldr. J.C.T. Downey, D.F.C., A.F.C.

R.A.E. Ref: I.A.P./S.3601/1

SUMMARY

Information on the philosophy and development of flight instrument systems in the U.S.A. gained during a month's visit in April - May 1955 is recorded.

There is considerable emphasis on integrated weapon systems of which the instrument display and navigation systems are part; the system most advanced practically is the Hughes MX.1179.

While there is in the U.S.A. no 4-axis gimbal platform equivalent to the MRG(A), there are 5 independent developments aimed at defining the vertical to 0.2°, i.e. with an accuracy intermediate between the MRG(A) and an inertia navigator.

Considerable attention is being paid to the possibility of displaying the tactical situation pictorially and to the use of CRT and optical methods of display. The U.S. places less emphasis than the U.K. on the problems of near vertical flight; the controversy between moving aeroplane and moving world in attitude presentation is still unresolved.

Some interesting and important work has been done on the problems of instrumentation for cruise control and engine handling.

The performance of the NAA Inertia Navigator under realistic conditions in an F86D is noteworthy.

LIST OF CONTENTS

APPENDIX

LIST OF ILLUSTRATIONS

1 Introduction

This note records the findings of a joint R.A.E. (I.A.P.) and Air Ministry (O.R.) mission to the U.S.A. on Flight Instrument Systems and Fighter Inertia Navigation with the particular objective of comparing U.S. and U.K. progress in the field covered by O.R.946[1].

Four main centres of activity in the flight instrument system field exist in the U.S.:

(a) W.A.D.C. who, in addition to their normal commitments in the instrument field, have just launched a comprehensive programme for the U.S.A.F.

(b) N.A.D.C., where activity seems to be limited to interim phases of the U.S.N. programme.

(c) The Douglas Aircraft Co. who act as central co-ordinator for a joint Bu Aer-O.N.R. project covering both interim and long-range programmes.

(d) The Hughes Aircraft Co. who are developing a flight instrument system as an integral part of the MX.1179 weapons system.

With the exception of N.A.D.C. the instrument system programmes are being treated as an integral part of the whole control system of the aircraft so the picture is not complete without the control aspects; these are being covered by another R.A.E. (I.A.P.) mission.

The activities quoted are mainly concerned with system study and analysis, psychological aspects of display, and system and display evaluation by flight and simulator tests; the basic components for the systems are usually developed to specification by the Instrument Industry.

Visits were made to such sections of the Industry as were known to be engaged on the programme but certain, possibly profitable, lines had to be omitted as they were not discovered until too late.

The fact that four independent groups exist each sponsoring developments of similar types of components makes for considerable duplication which will become apparent from the details of the individual visits.

In the fighter I.N. field, of the two known instances M.I.T. and N.A.A., the former project was terminated in April, 1955. The success of the N.A.A. navigator under realistic flight conditions in an F.86D is particularly noteworthy, as are many of the details of the system and components.

It was hoped to obtain a statement on U.S. policy on navigation of fighters and, in particular, on I.N. This was not possible; at W.A.D.C. there was reluctance to discuss the subject; at Hughes the possibilities of I.N. are only just being considered, the MX.1179 system operating on a combination of TACAN and automatic dead-reckoning.

Although not the primary objective of the mission, a number of interesting individual instrument developments are reported.

2 Bu Aer

An outline was given of the multi-stage development programme described in the O.N.R. pamphlet[2] already seen in the U.K. This programme

is being pursued at the instigation of Bu Aer and O.N.R. but is co-ordinated by the Douglas Aircraft Company.

The first of these stages has already been tried in a T.33 aircraft. It consists of a spherical attitude/heading indicator, Kollsman combined speed indicator (Mach/A.S.I.), veeder counter single pointer altimeter, and a number of conventional instruments. The sphere has a rotating equatorial portion carrying heading markings, and landscape and cloudscape markings on its hemispheres. The model index moves in roll and pitch, a loop being shown by inverting the model index at 90° of pitch. The flight tests of this interim stage have been generally unsatisfactory; this was explained as being due partly to faults in the presentation but also to poor organisation of the trial, to lack of concurrent simulator tests and to the inadequacy of the Shooting Star as a test vehicle for instruments for future fighters.

A verbal description was given of succeeding stages in the development of the system. It was evident that ideas for instrument displays have already changed since the illustrations were devised which are shown in the O.N.R. pamphlet; moreover, the tenor of the discussion showed that more changes are likely. However, as planned at present, it seems that the main features of the various interim stages of the programme will be as follows:-

(a) The use of a fully free sphere and fixed model index. Probable removal of the landscape and cloudscape markings. The use of cross pointers on the sphere to give flight director guidance for selected manoeuvres.

(b) The use of an analogue central navigation computor producing director guidance for a selected ground track. When coupled to a fixing aid this computor will sense a wind vector and will, if necessary, correct any wind vector already set into the equipment. The latest correct wind vector will be held in a memory circuit for use during the D.R. mode. Initially the desired track, and track made good, will be shown on a conventional compass display separate from the spherical attitude/heading indicator. At a later stage a peripheral compass card may be mounted on the case of the sphere and this display will then carry the track information. At this stage of development it is hoped to display the range of any selected target on a separate veeder counter mounted near the sphere.

Some mention was made of the final long term stage; however, this was not described in detail since the scheme was to be discussed later at the Douglas Company (qv). The centre-piece of the scheme is a display of a composite picture on the pilot's windscreen using the Willys flat plate C.R.T. The main reason for putting the display on the windscreen is to save cockpit space, but also because it will be possible to relate directly the objects displayed to their real counterparts outside the aircraft. There are doubts at Bu Aer. on the effects of this display on the pilot's outside vision; the phosphor compound used at present on the screen, together with the fact that the screen has four refracting surfaces, means that it is translucent rather than transparent at present. The actual picture on the screen is planned as a dynamic perspective display, the details of which will be finally determined by simulator tests running throughout the programme. Figures may be added by using a matrix between the electron gun and the screen.

A more general discussion followed on the philosphy of the programme and on dates. Bu Aer were unwilling to express an opinion on the long term scheme and thought that only tests would prove or disprove the idea.

On the question of moving indices versus moving background Human Studies have produced a lot of evidence in favour of moving indices, particularly for tracking tasks, but the Bu Aer staff did not see how full manoeuvre could be represented other than by using a moving background, as in the free sphere. The programme generally would be considerably behind the dates mentioned in the O.N.R. pamphlet: the first of the interim schemes mentioned above would begin simulator tests late in 1955. The official plan for the long range programme (Willys Tube) is to have it in a breadboard stage by 1958, but personal doubts were expressed on the realism of this date; as yet the basic data accuracies needed are uncertain.

Some discussion of current instruments then took place viz:-

(a) Lear Sphere. The two-tone Lear Sphere (without heading) has proved successful and the U.S.A.F. is intending to retrofit it in aircraft as far back as the F.84 and F.89.

(b) Kollsman Combined Speed Indicator. This has had a very mixed reception. In the 3¼" case the readability and accuracy are marginal and the IAS scale is definitely too cramped from 600K-850K. A revision is to be tried in which a slotted disc would be used showing only that band of the scale in use at any one time; the object of this is to reduce clutter. The U.S.N. think that at present the pilot has no need for a display of TAS.

(c) Altimeter with Counter/pointer presentation. This altimeter is well liked by the U.S.N.; the U.S.A.F. like the presentation generally but find ambiguities at the change over point (i.e. at 1000 ft intervals); however this obtains with a non-servoed instrument (limit 50,000 ft). A final report is being prepared now.

(d) Instrument Lighting. Some examples of current instrument lighting equipment were inspected. These were the original Grimes shield, the later edition of the shield (Grimes B.4876, R) and the Grimes miniature pillar. Current policy is to use a combination of the latest shield and the pillar light, according to the type of instrument to be lit.

3 W.A.D.C.

An outline of the U.S.A.F's flight systems development programme was given, starting with a description of the pilot's difficulties in controlling a supersonic aircraft; the factors mentioned were, in essence, similar to those responsible for our own O.R.946 programme. The U.S.A.F's first reaction to these problems was to plan for the very extensive use of automatics; but it was considered that they had overstepped the mark in this direction and were in danger of under employing the human pilot at the expense of great complexity. They were, therefore, now considering the use of a measure of flight direction for the pilot in conjunction with forced stick steering and other forms of improved controls; tests had shown that for some flight phases the human pilot using a flight director could produce as good results as automatics, e.g. in the runway approach phase. Great emphasis was placed on the importance attached to the integration of the work being done on instruments and control systems; the departments at W.A.D.C. concerned with these projects have now been organised into one team.

The discussion then continued in terms of broad philosophies. Repeated attempts were made to tie the discussion down to specific points and to discover some of the practical details of the programme; this met with very little success, all the W.A.D.C. officers appearing determined to talk

of generalities only. On being pressed still further for details, they announced that there was a definite programme in hand for the "evaluation" of a number of different items, including several alternative approaches to the problem as a whole. These items were then given as follows:-

(a) Automatic and Manual control systems.

(b) Flight Director presentations.

(c) Flight mode selection and flight path programming.

(d) Presentation of attitude and heading in all attitudes, together with the possible use of steering guidance provided by a data link.

(e) The measurement of angle of attack, Mach number and I.A.S.

(f) Engine instruments.

(g) Master warning system.

(h) Flight path displays.

(j) Terrain clearance and obstacle warning.

(k) C.R.T. displays with mode selection

(l) Integration of dynamic vertical and air references.

(m) The Collins Flight System and similar systems.

(n) Time and distance information displays.

(p) The Willys C.R.T. and colour television tubes.

(q) Infinity projection of instruments on windscreens.

(r) Three dimensional presentations.

It seems that a small number of these investigations are being made in the house, but that most are contracted to industry. There appear to be no definite applications for these projects and official policy is one of leaving no stone unturned in the hope of finding something useful. Despite this vagueness, it was claimed that the programme covers the needs of all classes of aircraft and that the aim is to produce a new system for fighter bombers within one year. Initially the system will consist of minor rationalisation of the conventional instrument display. It is evident, therefore, that apart from the separate Hughes Company project for the F.102, the U.S.A.F's instrument programme is far from being crystallised.

A flight simulator was shown, making use of the C11B trainer (T.33 aircraft) as the basic component; modification is needed for all attitude flight. It was equipped with a versatile C.R.T. display which enabled various forms of display and director indices to be quickly set up for evaluation. The performance of the operator is assessed by integrating the control reversal error.

Some discussion took place on the relative merits of moving indices and moving backgrounds. The officer in charge of the project seemed to be largely in favour of moving indices (e.g. of the Smiths "Beam Compass" variety) but said that he thought each method had its place and that it was necessary to keep an open mind on the subject. Dr. Graefer (a psychologist) was strongly

in favour of moving indices for small, panel mounted indicators. He claimed that extensive simulator tests had shown without doubt that the moving index was superior; he refused to admit that the back beam presentation of the "Beam Compass" or the moving model attitude indicator during a loop were at all confusing. However Capt. Wright thought that it was essential to move the background in cases where it was necessary to display heading and attitude unambiguously in all attitudes. Dr. Graefer qualified his view by saying that the value of a moving index was a function of the size and the texture of the display; as the size of the display is enlarged and as texture is added, the moving background display becomes progressively more acceptable until, on reaching life size and full texture, it becomes indistinguishable from a view of the outside world.

Two stable platform developments are being sponsored by W.A.D.C.

(a) 3 gimbal platform with 3 (6.5×10^6 c.g.s. units) gyros total weight 70 lb (Kearfott q.v.).

(b) 4 gimbal platform with 3 single degree of freedom gyros; total weight 27 lb aimed at 7 mins of arc local vertical under all conditions (Eclipse-Pioneer q.v.).

It was stated that the true 4 axis gimballed platform is more accurate than the 'quasi stabilised' system used in the MRG(A) and proposed by Lear (q.v.).

Details were given on the Eclipse-Pioneer and Kollsman air data computer developments (q.v.); these are both displacement systems. Norden Laboratories and Servomechanisms are both developing force balance systems.

The following points were made in connection with short term developments:-

(a) Accelerometers. The U.S.A.F. view the use of the indicating accelerometer in much the same light as the R.A.F., i.e. mainly as a training device. For future developments they are considering the use of either a $3\frac{1}{4}$" dial or else a reduction of the scale range from + 12g/ -10g to some smaller range. They are also considering remote reading accelerometers with the sensing unit near the C of G of the aircraft. There is also some talk of measuring the ratio of top and bottom wing surface pressures as an alternative to G. The object of this is to provide a more accurate indication of the approach to structural limits.

(b) Altimeters. The U.S.A.F. appears to be worried about the accuracy of the pressure altimeter when used as a separation reference for stacking at heights of the order of 20,000 ft and above; they did not explain what type of stacking would be resorted to at these heights. Correction of P.E. using mach and angle of attack terms is being considered; the actual method of correction proposed was to introduce a compensating pressure into the static lines; this seems to be a clumsy method if an air data computer, which can be compensated electronically, is in use. For presentation of height in the near future the 3 pointer altimeter with a periphery tens of thousands pointer and a warning flag opening fully at 10,000 feet has been chosen and large numbers of these instruments have already been ordered. The U.S.A.F. think altimeters can function satisfactorily to 120,000 ft without power assistance, but they agree that power assistance must be used eventually, particularly if the veeder counter type of presentation is to be used.

(c) Indicated Airspeed Presentation. W.A.D.C. are trying to convince pilots and aircraft manufacturers that angle of attack could be displayed usefully. An A.S.I. is being considered in which the pointer can be aligned with a periphery director pointer, the latter being fed from an angle of attack source and being moved over a scale divided into segments representing safe ranges for approach, climb, cruise, etc. This instrument is shortly to be tried in a B.47. It has already been decided that all new aircraft will have an angle of attack indication of some sort for the runway approach phase; the choice lies between the instrument mentioned above (made by "Specialities") and the "Safe Flite Indicator" which provides a null reading against any selected lift coefficient.

(d) Mach Number. Examples of the Kollsman combined speed indicator in various sizes of case were seen. All were notable for their lack of clarity. W.A.D.C. is proposing a slotted disc scheme (see Bu Aer) to improve clarity (similar to Kelvin-Hughes version 2). They do not seem to have considered schemes similar to the Mechanism instrument. It was claimed that panel mounted (integral) combined speed indicators would provide an accuracy of ±0.02M; if fed from the air data computer exhibited, the accuracy would be ±0.01M.

(e) Attitude and Heading. W.A.D.C. were critical of the discontinuities of the roller blind with periphery compass card. They are experimenting with spheres similar to our own and have already adopted the simple Lear "Two-tone" sphere (without heading) for most current jet aircraft. A model was shown of a sphere with heading; this had plain black and white hemispheres, the index model being white with a black outline.

(f) Lighting. Current practice is to use the Grimes system plus sandwich consol lighting. A new scheme was demonstrated in which new long life bulbs were fitted inside the rear of the case and a translucent prismatic bevel fitted behind the card; the results appeared to be excellent.

(g) Cruise Control. A cruise control instrument is being developed as the result of work done by MIT (q.v.). In its initial form this instrument will allow the pilot to set in various quantities and then fly the instrument to a null reading. The general intention seems to be that all aircraft will shortly be using an instrument of this sort as a primary power reference, although tachometers will also be retained.

(h) Collins and Sperry Flight Instrument Systems. The Collins system has been evaluated very favourably in a T.33 aircraft. The Sperry system has also been evaluated with indecisive results. No Service "fix" has yet been made for either of these systems.

(j) F.101 Instrument Panel. An F.101 instrument panel was seen. Apart from the Kollsman combined speed indicator and the Lear two tone sphere, it appeared to be wholly conventional. An edge lighting system was fitted and severe tunnelling was very apparent.

A visit was paid to the Navigation Laboratory and an attempt made to discuss the basic navigator requirements of fighter aircraft and in particular the future of inertia navigation. NAVATEC, which is a combination of fixes and D.R. aimed at an overall accuracy of about 5 miles, was mentioned but there was a marked reluctance to give details on I.N. performance and policy and, as the subsequent visit to N.A.A. demonstrated, some of the information given was misleading.

4 N.A.D.C.

The visit opened with a short general discussion on stable platforms and inertia navigation. The view was expressed that present all inertia navigation programmes are unrealistically ambitious and that a more reasonable initial approach would be to aim at lighter, less accurate platforms for mid-course guidance only, with reliance on other fixing and homing aids for completion of the sortie or upon correction of the IN platform by means of air data. The U.K. requirement for $\frac{1}{2}$ mile position accuracy prior to AI acquisition, which has arisen from a study of the navigation problems for collision course interception in connection with O.R. 329, was mentioned; a requirement for this order of navigation accuracy during interception does not appear to exist in the U.S.N.

The Naval flight instrument programme was outlined; the emphasis is on a completely integrated system embracing the problems of control, navigation and weapons usage. There are to be a number of intermediate steps culminating in an advanced system to be flown first in 1958. This advanced stage is being co-ordinated for Bu Aer and O.N.R. by the Douglas Company; the emphasis is to be on production of an early example of the advanced stage for evaluation, hence the ambitious date of 1958. The presentation of the advanced stage (i.e. the perspective picture on the Willys Tube) is based on an analysis of the basic requirements of the human pilot; it is considered that these basic requirements have been firmly established as a result of extensive Human Factors studies and simulator tests. The tenets of this scheme are described in a report[3] by Dunlap and Associates Inc., which lists 15 basic requirements for information to be presented to the pilot, of which the most crucial are held to be:-

(a) Motion

(b) Outside Reference

(c) Inside Reference

(d) Texture

(e) Linear Perspective.

Mr. Guarino and his colleagues did not appear to be in a position to discuss these factors in detail and it was therefore decided to postpone discussion of them until the visit to the Douglas Company (q.v), and also to obtain a copy of the report mentioned as soon as possible.

Returning to the programme as a whole, it was stated that the interim phases are intended to make the most use at each stage of available components. The first phase (already tested in the T.33 aircraft) had made the best possible use of more or less conventional instruments. The second phase will draw together new devices such as the stable platform (including the possibility of inertia navigation), the flight director principle, air data reference computers and automatic fuel and engine management equipment. By 1958 the various stages of the interim programme should have provided the means for achieving the long term advanced stage. N.A.D.C. are much in favour of the idea of ultimately providing a central sensing and computing station which would process and transmit in a digestible form the data required for all purposes in the aircraft.

N.A.D.C. has a C11B (T.33 aircraft) simulator for use in the instrument development programme.

The first item of equipment to be discussed was a manoeuvre computer for the instrument system; this computer is being built in prototype form at N.A.D.C. and will be complete "this year". The inputs to the computer for the climb manoeuvre will be angle of attack, attitude, Mach number, height and target height. Initially the computer will be based on the assumption that low rate turns only are necessary and that recovery from the climb will be by means of a "push out" (in fact it did not seem that N.A.D.C. had considered the possibility of a "pull out" being necessary, involving inverting the aircraft in the climb). It is planned to provide a manoeuvre control panel for the pilot, separate from the instrument panel; two reasons were given for this, firstly that the pilot is not always able to reach the main instrument panel, and, secondly, that use of flight instruments as setting devices complicates their design. The control panel will include three sets of control knobs; the first set will control mode in the horizontal plane (e.g. desired compass heading, desired track, desired target, and the use of VOR, TACAN or DR); the second set will control mode in the vertical plane e.g. radio or barometric height, ground speed, glide slope, and climb); the third set will control the quantitative references (e.g. Mach number, rate of climb, and target height).

The question of attitude presentation was then discussed. Cathode ray tube presentation of attitude is being developed at high priority on the grounds that it saves considerable space and overcomes many mechanical difficulties; the disadvantages of electronic complexity and, possibly, of unreliability were admitted but N.A.D.C. thought they would rapidly be overcome. At present however prototype mechanical spheres are being made under contract by Kearfott and several examples of these were seen. These spheres all had equatorial heading scales and non-rotating hemispheres; the possibility was being considered of marking heading on the hemispheres and rotating them. Two examples were seen having meter movement cross pointers for flight director presentation, but these models had three degrees of freedom only (i.e. pitch, roll and heading). A third sphere was seen which had a conventional compass verge ring surrounding the instrument case; in this instance a bank pointer had been mounted to work at the top of the verge ring, the pointer being geared to reverse its natural movement in order to allow for asymptotic roll out on to selected headings. Each sphere incorporated its own system of edge lighting.

Instrument lighting was discussed. Three schemes are under consideration as follows:-

(a) Electroluminescence. The Sylvania Corporation are working on a scheme for electroluminescent lighting which appears to be similar to the work done by Smiths except that yellow paints rather than red appear to be favoured owing to the difficulty of obtaining sufficient brightness with the red. There appeared to be no solution as yet to the problem of lighting a moving pointer having low torque.

(b) The Douglas Scheme. The Douglas system consists of mounting a small bulb in the centre of the front glass of the instrument and "dishing" the instrument card, (i.e. concave face towards the viewer). A demonstration of this was seen in which the card and pointer were very well lit, but the bulb obscured part of the scale unless the viewer's line of sight was almost normal to the panel.

(c) Eclipse Pioneer Scheme. A scheme produced by Eclipse Pioneer was shown, consisting basically of an edge lighting arrangement in which the plastic light conductor was fitted from 10 o'clock to 2'oclock only on the dial face. At 6 o'clock the front glass and the instrument card were in their normal relation to each other.

Helicopter instruments for all weather flying were discussed briefly. N.A.D.C. believe that the solution must include both artificial stabilisation and new instruments. They consider that their latest helicopter autopilots have solved the stabilisation problem. A development programme for instruments is under way based mainly on the measurement of rotor disc attitude and the provision of flight director displays for both collective and cyclic pitch control. The techniques for measuring disc attitude will be based on the measurement of blade flap angle. (Flap angle = tangent tip path plane, giving the lift vector). The U.S.N. do not consider that there is a need for displaying cabin attitude in addition to disc attitude. Apart from the presentation of disc attitude and director guidance, helicopter instruments are expected to be conventional.

5 North American Aviation

Fighter Inertia Navigation

As previously reported N.A.A. are working on an experimental fighter I.N. System (XN5) which is now being re-designed under the title "N5A" with the objective of producing four Service models in 38 months.

The XN5 inertia platform is 16" diameter by 24" long and weighs 70 lb. There are four gimbals, two fully free (outer roll and inner azimuth) and two with restricted freedom viz. pitch $\pm 110^o$ and inner roll $\pm 10^o$. The outer roll gimbal is servoed to the displacement of the inner roll gimbal with a gain that is a function of the pitch angle. It is designed to follow 16^o/sec. in pitch.

The gimbal system (Fig.1) is a combination of a conventional outer roll gimbal with inner rou gimbals similar to those used on the British M.R.G.(A). This results in an extremely neat package with a high ratio of volume of stable platform to total volume. The platform holds six single degree-of-freedom fluorolube floated gyros of angular momentum 3.6×10^6 c.g.s. units which are periodically reversed on an 8-minute time cycle. Also on the platform are distance meters, which are doubly integrating accelerometers somewhat greater in size than the gyros. The platform is aligned to the vertical at the point of take-off and is precessed with earth rate signals only, the reference signal being a Mallory cell. During flight the platform deviates from the vertical. The distance meters are, however, fitted with torque motors which are fed with correction signals from an analogue computer to compensate for coriolis acceleration and movement of the aircraft over the earth's surface. (In effect, this maintains the pendulous element of the accelerometer parallel to the vertical at take-off with an 84-minute period).

It is claimed that by torquing the accelerometers instead of torquing the gyroscopes the sources of error in the platform are separated from those in the accelerometers, thus considerably assisting development work. (To torque the gyros would, in addition, involve producing a velocity signal from accelerometer output).

The associated computer, including monitoring circuits, brings the total system weight up to 300 lbs excluding the inverters but no serious attempt has been made to miniaturise the computer.

Extensive tests have been made in an F86D including $3\frac{1}{2}$ g and Immelman turns. The position error during level flight was determined by cameras; during manoeuvre the only check on the navigator performance was by means of an 18-channel recorder. No effects due to accelerations were, however, observed which exceeded those due to the aircraft moving relative

to the platform (e.g. the magnetic effect of the aircraft). The results obtained in the last five flights (at 15,000 ft) are particularly interesting, an overall probable error of 3.6 n.m. in 1 hour being obtained; the peak errors were 5 miles radial and $1\frac{1}{2}$ miles cross-track. In this series 4 flights were made in one day, the other being on the evening of the previous day. In each case the navigator was shut down completely for re-fuelling of the aircraft, turned on 10 minutes before take-off and the N/S axis of the accelerometer aligned with a theodolite. No automatic change of the bias setting on the gyros was used, the bias setting holding from the previous day; in one case the bias was altered manually by 1/200 of a degree per hour but this was subsequently returned to the previous value. No attempt was made to reduce the alignment time to a minimum. During these flights the measured gyro temperature varied from 110°F to 40°F.

In the new N5A design, which involves a complete re-packaging, considerable attention is being given to making an operationally suitable design.

G5 Gyro

In the new gyro for the N5A navigator the main changes are to replace the flexural bearing on the sensitive axis by a fluid bearing and to reduce the angular momentum to 2×10^6 c.g.s. units. This reduction in momentum gives a 70-second reversal period for a speed of 12,000 r.p.m. the motor requiring 4 watts in synchronism and $11\frac{1}{2}$ watts on reversal. Details of the design are shown in Fig.2. The bearings, which are placed close together for ease of maintenance of pre-load, are a commercial bearing Barden 36 HX3-DB7 with a 7 lb pre-load and $35\frac{1}{2}°$ contact angle. The aim is a thousand hours bearing life which has been achieved on test. The two bearings are separated by a spring in the form of a cup-shaped washer with flat characteristics. Once the load is applied the bearings are cemented into an outer sleeve, and the spring is of no importance, serving only to maintain the pre-load during assembly. The rotor is a Diablo shaped wheel with an external motor. The wheel is enclosed in a hydrogen-filled case which is floated in F.S. fluorolube, the case-float separation being 15 thou. Damping is provided by the servo loop; originally separate velocity and displacement pick-offs were used but in the G5 design all the damping is provided by the servo characteristics. The float is supported on two fluid gimbal bearings. The fluorolube is pumped into the bearings by means of a solenoid-operated reciprocating pump delivering 5-6 c.c.s. per minute at 70-90 lb/sq in. through a 6 micron filter; fluid is forced into the bearing through an annular slot of $\frac{1}{2}$ thou. thickness. End location is provided on one bearing only to allow for expansion; this bearing, which can carry 300 grms load, is stated to have an uncertainty torque of less than 1/20 dyne.cm.

Prototype gyros have been tested individually for open loop stabilisation of the platform. Highly successful results have been obtained on test with four runs of up to 7 hours; as a vertical gyro the total variation in wander rate has been 2-3 thousandths of a degree per hour; unbalance of the gyro was equivalent to 15 dyne cms. As an azimuth gyro better than 1/100 of a degree per hour for a 5-hour period has been obtained with a 30 dyne cm unbalance. These tests were made under ambient laboratory temperature conditions which varied by 3-4°. During the tests signals were deliberately injected into the torque motor to check that the gyro would precess at a prescribed rate.

Integrating Distance Meter

The principle of the integrating distance meter has been reported previously viz. balancing the pendulous torque acting on a mass against the torque generated in accelerating a rotor, the number of revolutions of a meter then being the double integral of the acceleration and hence the distance

travelled. The distance meter is similar to the G5 gyro with a fluid bearing. Using a pendulosity on the wheel of 25 grm cms., the $^1/20$ dyne cm bearing uncertainty corresponds to an uncertainty in acceleration of 2×10^{-6}g, giving a levelling performance of the order of 2 seconds of arc. The scale of the meter is 25 ft/revolution with a resolver output.

N.A.A. claimed that the principles of reversing gyroscopes and the distance meter are proprietary to the Company.

6 Douglas Aircraft Co., El Segundo

The principles of the work on instrument display, as formulated by Cdr. Hoover of Bu Aer, are already well known in the U.K., being based on the philosophy of enabling the pilot to perform under all weather conditions as well as he can visually at present. Considerable effort (\$ 10^6 p.a.) is being diverted to the project.

An extensive study by a team of human engineers has established five main visual clues that a pilot uses; these are:-

perspective
texture
motion
inside and outside reference.

Demonstrations were given of how by texture or a series of perspective lines a realistic simulation of the flight of an aircraft over the ground could be made; the long range programme is based on making such a simulation as realistic as possible.

For interim displays the reverse, a moving aircraft index, is used, this choice being based on tracking tests.

This apparent inconsistency of policy was explained to be based on the premise that if the outside world can be presented properly (i.e. to create the correct illusion) then a 'moving world' presentation is ideal; if just an index is used however then a moving aircraft index is preferable.

Interim display

The interim attitude display uses a moving aircraft index displayed on a C.R.T. (being developed by Sperry). When 90° pitch is exceeded the tail index reverses to simulate "upside down". No effective answer was given to U.K. comments that this form of display results in control reversals during inverted flight.

Long term programme

The whole programme is aimed at a 'flying breadboard' by 1958.

Attitude display is based on the flat transparent C.R.T. which has been published in the technical press. So far only a continuously pumped version is available and considerable development is required to obtain a linear scan and produce a compact sealed-off version. Design of the necessary circuits for displaying the complex perspective pattern has yet to be tackled as well as the problem of displaying quantitative information.

The extensive instrumentation programme necessary to feed the display (as well as the display itself) is being tackled by sub-contract work, amongst which are the following items:

Technical Note No. I.A.P. 1050

Feasibility studies

Strike (Federal Telecon)
Take-off (Melpar)
Navigation and cruise (Lear)

Air Density Measurement by radiation absorption (Control Inst. Co,)

Temperature measurement Eclipse-Pioneer

Stable Platform. A specification has been issued for a sub-miniature IN platform to weigh 6-8 lb. One design study by Instrument Development Lab is apparently suggesting that this can be met with 14×10^3 c.g.s. unit gyros weighing $3\frac{1}{2}$ oz., on the assumption that such a gyro having given 2^o/hour on test, there is no theoretical reason why it cannot be improved by a factor of 100!

7 Hughes, Culver City

The MX.1179 semi-automatic all-weather flight and navigation system+ being developed for the F102B aircraft is an example of the execution of the weapons system concept. The system envisages operation of the aircraft under either close control from the ground, i.e. command by auto data link, or broadcast control from the ground, i.e. target data only, the interception being computed on the aircraft in a master digital computer. The aircraft navigates automatically to the point at which the target should be acquired, the pilot being given a continuous display of both the situation and commands so that he can monitor the situation. An airborne digital computer will give command speeds for one of 3 pre-selected modes: maximum speed, range or time. The predicted position of the target will be shown on A.I. but the pilot must perform lock-on, operate I.F.F. and select armament; the attack phase is automatic on radar. The radar (140^o sector or B scan) will discriminate leading or trailing edge of return to obviate window, and against ground return.

The aircraft will carry 3 radar homing missiles for automatic release on lead collision course, 3 infra-red homing missiles and rockets for similar release or on lead pursuit course optically at speeds up to $M = 2.3$ and from altitudes 10,000 ft below the target. It is considered that a high probability of kill will be obtained by firing 3 missiles, so provision is made for a new target to be assigned. There will be a transfer from G.C.I. to Tracal, on a different data link frequency, for return to base; up to 6 homing points will be stored in the digital computer for selection in case of failure of ground control. An auto approach coupler will be used with I.L.S.; at first the throttle will be closed manually for automatic flare-out and touch-down but an F.M. altimeter will be used later for this phase. Convair are studying automatic fuel monitoring whereby the throttle is set to a given speed based on the command Mach number calculated by the computer.

The central digital computer performs navigation computations employing dead-reckoning with wind corrected by TACAN fixes while within its range. Unsubstantiated azimuth accuracy figures of $1/10^o$ - $2/10^o$ were quoted based on AIL claims of tests by Federal.

The implications of inertial navigation are just being considered. No firm figure could be obtained for the accuracy to be aimed at for mid course guidance; 1-2 miles were quoted as the order aimed at (for a $M = 1$ target). Manual input of fix data is being provided for the R.C.A.F.

Only preliminary consideration had been given to interception in three dimensions; it is considered that the optimum climb programme would be stored in the central computer and fed to the pilots display.

A specification has recently been written for sub-contracting the air data analogue computer, whose outputs will be digitalised for the navigation computer; the accuracy aimed at is ±0.01M and ±0.25 per cent full scale +20 ft.

The cockpit is designed to optimise the man-machine system and give a reasonable division between man and automatics, the function of the automatics being to unburden the man from the flying of the aircraft and routine computation. The basic cockpit layout is shown in Fig.3.

The display comprises:

(i) C.R.T. flight path indicator (not attitude) in which a model aeroplane banks and pitches, the choice of moving aircraft being made as the result of tracking tests conducted on a C.R.T. type of display; the vertical movement will be made proportional to the sine of the flight path angle in order to open the scale; inverted flight is shown by inverting the 'fin'. No adequate reply was received to U.K. comments that control-display reversal obtains with this type of indication. It was stated that the main consideration is near-horizontal flight. Flight path angle is to be obtained by subtracting measured angle of attack from measured pitch of the aircraft from gyro datum. Commands to the pilot will be indicated by lateral movement of the model aeroplane and vertical movement of an index.

(ii) Actual, predicted one minute ahead, and target heights by pointers moving on vertical scale, 60,000' or 10,000' at choice, with 50' vernier, counter ground pressure setting and possibly tape or bar marker for terrain clearance.

(iii) Actual, command and maximum safe Mach number by pointers moving on vertical scale.

(iv) Indicated airspeed up to 400 knots (directly operated from capsule) with a parallel scale of angle of attack expressed in terms of airspeed so that the angle of attack pointer moves with the I.A.S. pointer for a lightly loaded aircraft. The scale is divided into three coloured regions, Red, Yellow, Green, the boundaries corresponding to touch-down angle of attack, and initial approach angle of attack, respectively.

(v) 10" diameter plan position indicator of target or base and interceptor. On the screen of this indicator can be projected an area of 100 mile radius for interception, 50 mile radius for traffic control, 25 mile radius for terminal guidance from a micro-film covering an area of 200 miles radius around a TACAN station. A workshop model of this projection system, chart magazine, target graticule translation mechanism, interceptor graticule translation and rotation mechanism, heading and command course servo-systems was seen nearing completion of assembly during our visit.

A new form of control has been developed for controlling the A.I. scan during lock-on; this is a miniature stick moving fore and aft to control range, laterally for azimuth and with a thumb-roller to control elevation. It is claimed that probably lock-on time has been reduced from 7 to 3 secs by this control.

The central digital computer in the present form weighs 200 lb including input and output and uses sub-miniature valves; a transistor version is under development. The store is a magnetic drum with 60 channels of capacity 64, (17 bit) words. Computations are made sequentially at a rate determined by the nature of the data.

8 Lear, Grand Rapids

In the Vertical Gyro Indicator System a 5" repeater type instrument, operated from a remote vertical gyroscope, presents, behind a fixed aeroplane silhouette, a moving horizon, as depicted by the division between dark and light areas of a spherical surface, which has full freedom in roll and $\pm 85^{\circ}$ freedom in pitch. A circumferential bank and vertical expanded pitch scale are provided. When necessary the moving horizon can be trimmed manually to coincide with the aeroplane silhouette for attitudes from 20° nose-up to 10° nose-down. A power failure warning indicator is incorporated.

The gyroscope, which can provide a vertical reference for autopilot and radar stabilisation as well as two of the above indicators, is of all steel construction; its angular momentum is 8×10^6 c.g.s. units and wander rate 15°/hr (expected to improve to 10°/hr as production proceeds). Erection to the apparent vertical is controlled by a liquid level switch linearly up to 0.5° displacement; the electrolyte used is a closely guarded trade secret. During turns pitch-bank erection is brought into operation automatically by a rate gyro which senses the direction of turn.

This V.G.I. System is being produced at the rate of 300/month, possibly increasing to 1000/month, for both U.S.A.F. and U.S.N. who are fitting it retrospectively in place of the J.8 Artificial Horizon. During a test flight in a Dove fitted with this indicator the excellent pitch indication provided by the expanded scale was evident and the two-tone presentation was particularly attractive.

The liquid level switches mentioned are sold separately for 140 dollars each or, in quantities of 500, 120 dollars each.

Design of the All-attitude Flight Indicator and Two-gyro Master Flight Control described in the brochures[5] forwarded by B.J.S.M. in January, 1955, has not started as the firm has not yet been given a contract.

The magnetic powder used in the firm's autopilot clutches is another closely guarded trade secret.

Four-Gimbal Platform

A four gimbal platform is being developed based on the three gimbal platform used as a vertical reference in "Bomarc". The single degree of freedom gyros have an angular momentum of 6×10^6 c.g.s. units with $\pm 15^{\circ}$ freedom and ball bearing suspension. Extensive drift measurements have been made under $\pm 7^{\circ}$ platform oscillations. The drift is measured in six different positions over six consecutive 5 minute periods for all three of the platform gyros; 50% of these 108 readings lie within 1°/hr and 99% within 3°/hr.

Erection is by the electrolytic liquid level which aligns the platform to 0.01° statically. During normal flight this pendulous erection is used together with correction for Earth's rotation, coriolis acceleration, and open loop airspeed correction. The pendulous erection is cut off at 10°/min rate of turn or at an acceleration of 20 m.p.h./min.

Except for the outer roll axis A.C. torquers are used on the gimbal axes to avoid servo motor inertia; this enables pitch rates of 200°/sec. to be followed. A neat "pancake" design of concentric torquer, synchro and slip rings has been developed. As a three axis platform the weight is 24 lb plus 12-15 lb for amplifiers and control unit. The weight of the four-axes platform is expected to be 60 lb with computer.

9 Eclipse-Pioneer

Stable Platform (4 axis)

A very neat 4 axis stable platform has been developed which weighs 27 lb with amplifiers, occupies 800 cu. in. and is aimed at $\pm 1/10^{\circ}$ apparent vertical in flight.

Redundant roll gimballing is used with $\pm 43^{\circ}$ freedom on the redundant axis; the outer roll gimbal is continuously slaved to the inner at all pitch angles, rotation of the gimbals occurring when passing through the vertical. Maximum rates and accelerations are 200°/sec; 30 rad/sec^2 in roll; and 35°/sec in pitch.

The stable platform holds three 4×10^6 c.g.s. units ball bearing gyros. ($\frac{1}{8}$" dia. gimbal bearing). These are of completely symmetrical design (4 input leads are used to maintain symmetry), the gimbal and housing being of Invar. The whole unit is hermetically sealed and designed as a plug-in unit.

Wander rate figures are quoted with a $2\frac{1}{2}^{\circ}$ table oscillation, it being assumed that the gimbal bearing will always be exercised during flight. In one particular case an azimuth gyro was constant to $2/10^{\circ}$/hr over 13 hours; more detailed test figures were not readily available.

Erection is by a mercury-thallium switch which will handle 2 watts and enable external amplifiers to be eliminated. A mechanical integrator (low inertia motor and potentiometer) is used to torque the gyros for velocity. No air reference signal is used (although this is being considered for another platform - details not disclosed).

Accelerometers are being considered for the next step in development.

Magnetic amplifiers with subminiature valve inputs are used throughout.

'Roller Blind' Attitude Indicator

As an alternative to a small spherical attitude indicator a 'roller blind' type of indicator has been developed within a $3\frac{1}{4}$" case. The blind is 1 thou. stainless steel driven by sprocket holes at the centre, the pitch drive being carried on the supporting frame which moves in roll (at up to 270°/sec). 60° of the scale is visible through a 2" square aperture in the instrument dial. Several experimental models have been made for evaluation by the Navy.

Air Data Computer

The basic computer which gives T.A.S. and M(0.2 - 2.5) has already been inspected in the U.K.

A universal computer is being constructed (weight 20 lb) which gives relative density, true temperature, altitude, M, T.A.S. with an error $\pm 1\%$ up to 1000 knots and a maximum error of 10 knots at 2,000 knots.

Position error correction has not yet been considered, nor has any serious attempt been made to reduce the 12 cu. in. static volume.

Miscellaneous

Amongst the items viewed in the laboratory were:-

(a) Cruise computer which calculates the ratio of weight to relative density and indicates optimum altitude (based on work at M.I.T. q.v.).

(b) Navigational display, consisting of a projection of a map which moves with aircraft range, a central aircraft index rotating with heading.

(c) Rho-theta computer with the following features:

set in any number of alternate targets
indicate collision course on a moving target
find wind on TACAN data automatically, or from visual fix
weight 45 lb range 1200 miles.

The neat design of this computer has been made possible by the development of miniature sine-cosine potentiometers by the Computer Instruments Company of Brooklyn and based on a shaped carbon film; these have an accuracy of 0.5% for a diameter of 1" and weight of 1 oz; two units may be ganged without loss in accuracy.

(d) An experimental C.R.T. display of the Douglas-Hoover type (q.v.) using digital techniques for producing the pattern.

10 Kearfott Co. Inc.

Deliveries of Accelerometers and Gyroscopes (T.2500) ordered by U.K.

At the date of the visit (10 May) it was stated that two more accelerometers had been sent (making three in all), four more promised by the end of that week, followed by deliveries of two per week. Some modifications had been made to the design viz., the suspension had been modified to a thin-walled tube which is crimped in two places at right angles to give lateral freedom whilst maintaining torsional rigidity. This modification has raised the forced frequency to 120 c/s; minor modifications have been made to the amplifier circuit to ensure stability.

Considerable difficulty has been experienced by Kearfott in establishing control of manufacture and only a 50 per cent yield of piece parts has been obtained. Priority in supply of the few gyros manufactured has been given to Northrop on which a prior order of 34 gyros still remains for delivery. It is hoped that monthly deliveries from May to September will be 9, 7, 25, 50, 12. The best promise that could be made for the U.K. was a very tentative 3 in June and 3 more in July. Some modifications are planned, namely, reduction of speed to 12,000 r.p.m. and opening holes in the gyro wheel case to allow helium to be circulated throughout the case. It had been demonstrated that a torque could be generated without fluid movement by heating the gyro on one side, for example, a 50W infra-red source at 18" distance induced a wander of $4/10^{\circ}$ per hour.

Stable Platforms

3-Axis Platform for Lockheed

This 3-axis platform has three 6×10^{6} c.g.s. units single degree-of-freedom gyros with ball-bearing suspension on the sensitive axis. Liquid damping is used for simplicity. The gyro has the same wheel as the T.2500 flotation gyro and on azimuth tests has given a random wander rate of $\frac{1}{2}^{\circ}$/hr, the total wander due to mass unbalance and random component being of the order of 1°/hr. Two to four times improvement is obtained as a vertical gyro. The accelerometers are pendulums mounted on synchros having

a range 1g to 0.5×10^{-3}g. The weight of the platform is 27 lb; the total weight of the system is 55 lb. As originally conceived a linear erection system of $\frac{1}{2}^{o}$/minute + earth rate correction was used.

On subsequent platforms it is planned to use torsional suspension on gyros and schuler tuning. If the measured aircraft acceleration is large for a given time then the system will be run as an 84-minute pendulum with 5 per cent critical damping. For small aircraft accelerations 8.4-minute period and 50 per cent critical damping will be used. No air velocity damping is proposed. It is hoped that a vertical to 7 minutes of arc will be obtained.

4-Axis Platform (developed for Hughes)

A 4-axis platform with inner roll gimbal having $\pm 30^{o}$ freedom has been designed. This uses two 6×10^{6} c.g.s. units torsion suspended gyros for the vertical giving $\frac{1}{4}^{o}$/hr maximum total wander rate with a random component of $1/10^{o}$/hr. The 9×10^{6} c.g.s. units azimuth gyro has a wander rate of $\frac{1}{2}^{o}$/hr. A simple erection system giving $\frac{1}{2}$ to $\frac{1}{4}^{o}$ vertical is used, the system weight being $31\frac{1}{2}$ lb.

Precision Azimuth

A precision azimuth has been developed with two non-flotation gyros stabilising one flotation azimuth gyro. An azimuth reference better than $1/10^{o}$/hr has been obtained.

I.N. Components

The following components are being developed for a Navy I.N. project:-

(a) New Gyroscope

Angular momentum 2.5×10^{6} c.g.s. units. This has a beryllium copper float and case, little viscous damping being used. Damping is provided electrically by shaping the servo filter. The gyro motor circulates helium in the float. To ease amplifier design a large torque motor has been fitted; this consists of 12 permanent magnets operating on a ring type coil embedded in filled resin. Sufficient torque is obtained to precess the gyro at $1/10^{o}$ hr with 1 µA current. 4,000 c/s has been adopted for the pick-off frequency.

Distance Meter

An integrating distance meter is being developed, the aim being to produce one that is one third of the size of the N.A.A. development (q.v.). The sensitivity is 10^{-5}g (measured by observing stability of speed). A scale accuracy of 1 in 10^{4} is claimed; the construction is similar to the gyroscope, jewel bearings being used for the pivot; the system has a 15 c/s natural frequency. Weight is 2 lb, size 3" in diameter by $3\frac{1}{8}$" long; 3g maximum range, 15'/revolution, maximum speed 600 knots. Synchro take-off is used.

Integrator

A floating drag cup integrator has been developed. The instrument operates on a torque balance principle, the torque exerted by a D.C. torquer being balanced against that produced by a magnet rotating inside a drag cup. The torque balance is detected by a pick-off which drives the motor

rotating the magnet, where angular velocity is thus proportional to input current. The high accuracy is achieved by floating the sensing element (D.C. torquer and drag cup). A linearity of 0.02 per cent full scale with a threshold of 0.002 per cent is claimed.

11 Kollsman

Air Data Computer

This operates on the displacement system, transducers being used, which with suitable cam correction, give a logarithmic output on a synchrotel. Strong arguments were advanced in favour of displacement systems compared with force balance.

Computations are then performed by suitably adding and subtracting outputs of servo repeater shafts in the computer. M is displayed directly without any anti-log being performed, log $\Delta P/P$ being sufficiently linear.

An approximately logarithmic output for temperature is obtained by shunting the resistance thermometer with an appropriate resistance. Experiments were reported on the measurement of temperature by a flash bulb on an inlet duct; if suitably located a 100 per cent recovery factor can be obtained without any danger of icing.

Relative density is computed and integrated to give true altitude direction from a given zero.

Some difficulty is experienced due to noise in obtaining a rate of climb output.

Photoelectric Sextant

An automatic photoelectric sextant has been developed and extensively tested. The field of view is scanned at $33^1/3$ c/s with a rotating shutter, and selection circuits are used operating on the brightness. Tests have been made at up to 40,000 ft both day (sun operation) and night.

A single shot error (90 per cent limit) of 4.6 min has been obtained with a probable error over 4 shots of 0.9 min.

12 Sperry, Great Neck N.Y.

For commercial use the firm has developed the integrated instrument system which is illustrated diagrammatically in Drg. 5231-90472-C[6] and described under avionics in Aviation Week[7] of 10.1.55. From these it will be seen that in the S.A.E. standard panel -

(i) the Radio Magnetic Indicator is replaced by the C-6 RMI-gyrosyn compass. As its nomenclature implies this indicator combines a rotating compass card with two pointers which may be driven from either ADF or VOR receivers; a separate heading selector for the flight director is also obviated by incorporating a settable course marker,

(ii) the artificial Horizon is replaced by the HZ-1 Horizon Flight Director. This repeater type instrument, for operation from any remote vertical gyroscope, presents a moving horizon, as depicted by the division between dark and light areas of a spherical surface, which has full freedom in roll and $\pm 90^\circ$ freedom in pitch. As its nomenclature implies the conventional cross pointers of a flight director are embodied. The cross pointers and moving horizon are both referred to a central circle on the cover glass, representing the aeroplane. A circumferential bank scale and vertical non-linear pitch scale are provided,

(iii) the ILS Indicator is replaced by a Pictorial Deviation Indicator, in which glide path and localizer displacements are indicated in the conventional manner by translation of horizontal and vertical pointers, but the latter is V-shaped and so controlled that its apex is uppermost when flying towards the localizer and reversed when flying away from the localizer. Moreover when the localizer heading, as indicated by a Veeder counter, is set in manually any difference between aircraft and localizer heading is indicated in the correct sense by rotation of the V pointer.

The gyroscope, which provides the vertical reference for the two horizon flight directors, autopilot and radar aerial stabilisation, is of all steel construction; its angular momentum is 7×10^6 c.g.s. units and wander rate $7°$/hr. Erection to the apparent vertical is controlled by an alcohol switch linearly up to $2°$ displacement, at which the erection rate is $2°$/min. During turns pitch-bank erection can be brought into operation or erection cut out automatically if the rate of turn exceeds $10°$/min. or, if less precise correction suffices, at a particular bank angle. Provision is made for compensation of errors due to fore and aft acceleration but no means has been decided because of the difference in speed at take-off and height.

No engineering details were available of the engine monitor in which, on the drawing quoted, four quantities from each of four engines are indicated on a cathode ray tube.

This integrated instrument system, together with the A12 I pilot and automatic approach coupler, will be installed in the DC7C aircraft which B.O.A.C. is obtaining. It was hoped to have flown in the firm's aeroplane which is fitted with this system but it did not return from Texas in time.

The firm has developed a stable platform, carrying three single axis gyroscopes, with a redundant roll gimbal. Its bulk is 700 cu. inches, and its weight including amplifiers is 25 lb. The spherical cased azimuth gyro has an angular momentum of 7×10^6 c.g.s. units and a wander rate of $2°$/hr; the flat cased pitch and roll gyroscopes have each an angular momentum of 3×10^6 c.g.s. units and a wander rate of $5°$/hr. Liquid level switches control a linear erection system. The speed of a pendulous rate gyro is varied linearly with true air speed to secure compensation of errors due to fore and aft acceleration and turns. Compensation for earth rotation, earth profile and Coriolis acceleration is incorporated. It is hoped that the accuracy with which the vertical is defined will be 6 min up to speeds of $M = 2$.

Some consideration is being given to a system employing two two-axis gyroscopes in preference to three single axis gyroscopes because the former has some memory in the event of power failure.

Little further work appeared to have been done on the Gyratron in the absence of a suitable application; a wander rate of $1°$/hr with long integrator time (unspecified) was claimed.

13 <u>G.E.C. West Lynn</u>

The primary purpose of this visit was to determine the status of the firm's mass flowmeter. The following information brings up to date that given in R.A.E. Tech. Memo I.A.P. 490, pages 16, 19 and 20.

The power unit provides a 3 phase 4 c/s supply, to within 0.1% at normal temperature and 0.25% at the specified temperature extremes, for the constant speed impeller in the metering unit; its outout is sufficient for

8 metering units and it has recently been redesigned to reduce the weight from $5\frac{1}{2}$ to $2\frac{1}{4}$ lb; the power consumption is 1.25 amp at 25 volt. The metering unit covers the range 500 to 12,000 lb/hr with an accuracy of ±40 lb/hr; in its design considerable use has been made of magnesium alloy, protected by the HAE process, the weight of the metering unit being $5\frac{1}{2}$ lb; the Magnesyn transmitter originally used has been replaced by a second harmonic transmitter so that only magnets are now immersed in the fuel; the pressure drop is 0.2 p.s.i. at 6000 lb/hr. The scale of the indicator, which weighs 0.8 lb and has a 2" case, is expanded up to 3000 lb/hr and then contracted up to 12,000 lb/hr for take-off, the accuracy of calibration being ±10 lb/hr. Summation of flow rates to individual engines is achieved by incorporating in each indicator a potentiometer, which makes contact 4 times a second (to minimise friction) and straightens out the scale, so that voltages can be added and applied to a servo operated indicator in the larger standard case weighing 1.2 lb. Integration to obtain mass fuel consumed has not been considered as this is not a U.S.A.F. requirement. The metering unit, by modification of the input section, which increases the weight to 8 lb, can be used for flow rates of 24,000 and 45,000 lb/hr; for refuelling, a metering unit (weight 14 lb) has been developed with a pressure drop of 1 p.s.i. at 4,000 lb/min, the power unit previously described being adequate for 3 such metering units.

A copy of the firm's report[8] DF54M1-186E "Engineering report on qualification tests of GE fuel flowmeter system for Boeing Specification D10-1611F" dated 22.3.55 is being forwarded via B.J.S.M. The system first described has undergone a 1200 hour endurance test with satisfactory results; no manufacturing troubles have been experienced in the production of 8,000 metering units. The equipment is standard in B47 aircraft, in one of which 15 hours flying (including the summation indicator and lighter power unit) had been successfully completed the previous week at W.A.D.C.

As the production contract for Boeing has been completed and deliveries are now being made direct to the U.S.A.F. at the rate of 180 per week, there seems no reason why the long standing obligation of the A.S.C.C. to supply a sample to the U.K. should not be met. If not one should be purchased (cost about 1000 dollars), as the only mass flowmeter in production in the world, for evaluation of performance and possible manufacture under licence in the U.K., provided the Air Staff will waive its requirement for integration.

For use with its percentage tachometer the firm is developing an engine driven generator to withstand 125°C.

In production for the U.S.N. is the M.A.I. compass system (total weight $17\frac{1}{2}$ lb) in which a 4×10^6 gyroscope of 2 to 3°/hr wander rate, with one gimbal inside and the other outside, is monitored by an earth inductor element.

This firm has also appreciated the need for a vertical and heading reference to fill the gap in accuracy between gyroscopes in Service use and expensive inertial systems. It is therefore studying the design of a stable platform, using gyroscopes of 0.25 to 1.0°/hr wander rate, which is expected to be not more than 10 inches in diameter and to weigh less than 25 lb.

To replace the conventional thermocouple and millivolter, and enable high resistance leads of lower weight than the conventional compensating leads to be used, the firm is developing a servo operated potentiometer-thermometer which appears similar to that developed by Sangamo-Weston in the U.K.

14 M.I.T.

Cruise Control

A detailed study has been made for W.A.D.C. (M.I.T. Cruise Control Project Contract No. AF.33(6167-2329)) and the final report on the study phase is now being prepared. Attention has been focused on maximum cruise range for turbo-jet long-range aircraft.

For aircraft which are not limited in performance by thrust and can reach the critical Mach number, at which drag rises steeply, it can be shown theoretically that maximum range is achieved by flying the aircraft at the critical Mach number and then minimising the drag by selection of optimum altitude. This usually gives a cruising altitude about 12,000 ft higher than that for which the aircraft becomes M limited. This optimum cruise involves a small rate of climb ($^1/10^o$ climb angle or less) and is, therefore, only worth-while on long flights.

Choice of parameters for controlling the cruise is critical as the range is more sensitive to some parameters than others. For example, M must be held to 0.01 - 0.015 for a range within 99 per cent of the optimum; the corresponding altitude tolerance is $\pm$1500 ft. A third parameter is used - engine pressure ratio which is directly related to throttle setting; this, in effect, gives a rate feed-back term.

There are two approaches to the instrumentation; the first depends on having an accurate estimate of aircraft performance data which are then built into a computer to determine optima and the second in which an optimum is continually sought during flight. For the first approach the quantities selected are M, W/δ (W = aircraft weight, δ = ambient/sea level pressure) and engine pressure ratio.

Two phases of operation are possible:

(a) measure W/δ and show the optimum M for flight at that W/δ,

(b) set in the desired M and show the optimum W/δ.

The instruments are shown in Fig.4. The mode selector switch on instrument (1) is operated on either of the two modes (a) or (b). In one position the selected Mach Number (selected on Machmeter instrument (2)) is displayed. The optimum altitude is then indicated on the deviation meter, the disposable load having been set in. In the alternative mode the optimum Mach Number at which to fly is indicated on instrument (1) for the particular weight and height; this is then set on instrument (2) and the M deviation scale used to hold M (or a Mach hold autopilot).

In the second approach use is made of the fact that the specific range peaks at a certain speed. If the slope of the specific range-speed curve is measured then the aircraft is flown at the speed which gives zero slope.

During the 'continuous hunting' for the maximum speed has to be varied - this is done at the expense of potential energy and consequently height variations result. The success of the method depends on keeping the amplitude of the hunting sufficient low so that there is not a large change in drag (which would give extra loss).

Instrumental difficulties are encountered in choosing parameters which are sufficiently free of noise to enable the maximum to be found sufficiently accurately.

The important principle in this second method is that aircraft performance figures do not have to be known and the system therefore not only takes into account different types but individual characteristics of different aircraft.

The two possible methods of controlling performance, viz., storage of known aircraft data or determination of the optimum during flight have tentatively been considered by R.A.E. for optimum climb and it was agreed by M.I.T. that the principle of searching for an optimum could be applied to any performance characteristic that has a maximum.

Fighter Inertia Navigation FINE

The possible termination of FINE has been known in U.K. and it is confirmed that work terminated at the end of April. A final report is now being prepared.

On ground tests of three hours 8-mile longitude and $13\frac{1}{2}$-mile latitude errors were obtained. Only a limited number of flight tests were made - and these were insufficient to enable normal design faults to be cleared. In particular the performance of the HIG5 gyros under acceleration was considered unsatisfactory and subsequently 2HIG6 and 1HIG5 were used.

Work is now being started on converting the platform to an inertia extrapolator for radio or other navigational aids.

SPIRE Junior

A mock-up of the new gimballing system for Spire Junior was seen. A 'basket' type range gimbal is being designed (Fig.5). The inner platform has the three gyros arranged in such a manner that the same corrections can be applied to each; this platform is driven by a clock; a gimbal ring mounted at the end of the basket carries the range and across track accelerometers, the latter being mounted on a gimbal giving $\pm 15^{\circ}$ freedom to permit of ± 900 n.m. deviations from great circle track. The 'basket' range gimbal is mounted on conventional roll and pitch gimbals.

Integrating Accelerometer

Full details of the integrating gyro accelerometer were collected by Mr. Sedgefield of Sperry on the previous day. Magnetic centering is used for the sensitive axis with a radial stiffness of 5 gms/10^{-4} inch, the reaction torque being 2-5 dyne cms for a rotation of 45°. Total deviations from linearity of 5×10^{-5}g have been measured, the form of this residual error being a cos 2θ law.

15 Conclusions

15.1 General

In general the trend of U.S. instrument development is the same as our own, namely to achieve:-

(i) A simplification of the pilot's interpretation and control process by means of the flight director principle and automatic controls.

(ii) An extension of the scales of the flight quantities displayed and a general improvement in the form of presentation.

(iii) A significant saving in instrument panel space.

However, in following this trend there are differences in degree between U.S. instrument development and our own, the main differences being:-

(a) The extent to which the systems concept is being exploited as exemplified by the Hughes MX1179 system. In this system integration of the aircrafts electronic equipment has been taken to an advanced stage in that a central digital computor is to be employed for the serial computation of functions associated with the weapons, navigation, instrument and flight control systems. Such techniques are assisted by the availability of transistors and other sub-miniature components.

(b) The fact that development resources are large enough to enable long term work on display techniques to run parallel with development for the near future. This is exemplified by basic work on C.R.T. and optical methods of presentation and by the radical changes proposed in the Douglas-Hoover project.

(c) The emphasis on orientation displays of tactical information. Both the Hughes and Douglas projects include displays of navigational and tactical information on the same principle as that envisaged at present for our own system but on a more elaborate scale. This trend stems from the philosophy that in aircraft controlled automatically throughout flight, the pilots display should give first place to data required for exercising tactical judgement and second place to direct flight control data.

15.2 Stable Platforms

No four-axis gimbal platform exists in the U.S. similar to the M.R.G.(A); the Lear proposal for a platform similar to the M.R.G.(A) but smaller, lighter and more accurate exists only as a paper proposal hoping to obtain U.S.A.F. support.

The four-axis platforms under development in the U.S. are all aimed at giving a vertical to $1/5^\circ$ to $1/10^\circ$, that is intermediate in accuracy between an inertia navigator and conventional vertical references; five independent developments aimed at this target were seen, mainly at the stage of the first experimental model. These are all 3 single-degree-of-freedom non-flotation gyros usually with ballbearings on the gimbal axis; the stable platform is then supported by four gimbals, using an inner (or redundant) roll fourth gimbal. Random gyro wander rates of the order of 1°/hour were quoted; it should be noted that this figure is obtained whilst the gimbal bearings are being exercised on an oscillating table.

Erection systems vary from electrolytic switches with suitable cut-outs for bank and acceleration to linear accelerometers with, in one case, the period and damping of the pendulum loop being varied as a function of the applied acceleration.

The neatness of packaging made possible by the availability of small components is particularly noticeable. Most of the platforms weigh less than 50 lb including amplifiers, the outer gimbal dimension being of the order of 9". The Eclipse-Pioneer design is particularly neat, weight 27 lb, size 10" × 9" × 9" including amplifiers.

Future U.S. flight instrument and control systems will, therefore, almost universally be operating with a platform giving a $1/5^\circ$ to $1/10^\circ$

vertical, i.e. 10 times more accurate than that expected from the M.R.G.A.(A). The development of a similar source in the U.K. as already proposed for O.R.946, becomes a matter of some urgency.

15.3 Central Air Reference (Air data computer - U.S. terminology)

Developments of both displacement and force-balance systems have been sponsored by W.A.D.C. Unfortunately the existence of the force-balance developments was not known until too late to arrange visits, so only the Eclipse-Pioneer and Köllsman displacement systems were seen. Basically the systems are similar, employing logarithmic computation; the Köllsman is more flexible in that remote transmission can be used, if desired, between the displacement transducers and the computer (although these are normally packaged in one box). The Köllsman is in production but only a prototype of the Bendix was seen.

15.4 Basic Problem of Attitude Presentation

The problem of whether to move an aircraft index (external presentation) or to use a fixed index and move the outside world (internal presentation) has received considerable study.

It was universally stated that results of tests on which a moving aircraft index is 'flown to' a spot, positioned with respect to a fixed horizon, show less error and less learning time than the reverse, viz., a fixed aircraft index and a moving spot and horizon. On this basis a moving aircraft presentation is being adopted for the Hughes and interim Douglas presentations. The inevitable difficulties with this type of presentation in near vertical or inverted flight appear to have been ignored.

It was also stated both by W.A.D.C. and Douglas that these results apply specifically to flying on an index and that if a sufficiently true simulation of the outside world is presented then no difficulty exists with a 'moving horizon'. The work at Douglas is directed at producing such a true simulation by perspective and other means.

Accepting this thesis there would still appear to be a wide field between the two extremes of a pure index and such a comprehensive simulation of the outside world as Douglas are attempting, and the region in which an indicator changes from one type to another does not appear to have been investigated. Specifically, the benefits resulting from two-tone or textured presentations of adequate size do not appear to have been evaluated.

Throughout the U.S. little attention is paid to flight near the vertical, it being assumed that such a condition is transitory and that the display should be the optimum for near horizontal flight. Careful consideration should be given to the extent to which U.K. development is being complicated by the accent placed on near vertical flight.

An analysis of the fundamental principles incorporated in the Douglas-Hoover perspective display should also be made (the U.S. approach being more an 'act of faith' than a reasoned analysis).

The extent to which many different types of display can readily be evaluated by a versatile cathode ray presentation was noted; care should be taken, however, in extending these results to non-C.R.T. types of display.

15.5 Attitude Indicators

Considerable success has been achieved with a small ($3\frac{1}{4}$" instrument) two-tone sphere developed by Lear - this shows roll and pitch only but gives

a very clear presentation and is to be fitted retrospectively to many U.S. fighter aircraft. Although in principle the Eclipse-Pioneer roller-blind should give an equivalent display, little interest in it appears to be shown by the Services and it is still awaiting evaluation. The presentation is not so clear as the sphere, only a 2" square blind being used, and it can be criticised also for only showing 60° at one time on the pitch scale. Both these indicators have two degrees-of-freedom only - roll and pitch - and on passing through the vertical the display rotates in roll as rapidly as the servo-drive can achieve.

Policy on combining attitude and heading presentation is not very clear - in one case (the interim U.S.N. programme) a sphere is being used purely to give heading. The development of the Lear four-gimbal sphere with heading is, like the gyro source to operate it, only a paper proposal. Several proposals were seen for a normal compass card to be placed around the aperture of an (spherical) attitude indicator; this is coupled with an index for reading heading at the top of the card, the index and card rotating with bank in the opposite direction to rotation of the attitude indicator; this gives the usual asymptotic approach to the desired heading though some criticism was voiced that a true asymptotic approach is too slow in response.

Thought in the U.S.A. is however turning to solutions similar to those in the U.K. i.e. meridians on the sphere or a circumferential band in the horizontal plane.

15.6 Director Information

It is the U.S. intention, as it is in the U.K. to combine director monitor information in essential instruments. Three varieties of director are being considered viz. change of attitude, attitude demanded, and performance direction (i.e. rate pointers on A.S.I. and altimeters).

15.7 Fighter Inertia Navigation

The performance obtained with the N.A.A. Inertia Navigator under realistic flight conditions in an F.86D should be particularly noted. The reversal principle as applied does not attempt to make up for poor gyro performance but enables high quality gyros to be used for navigation without any attempt being made to achieve temperature stability; outstanding performance is being claimed for the new G5 gyro. The packaging of 6 gyros and 2 bulky double-integrating accelerometers within a platform weight of 70 lb is made possible by a very neat gimbal design which should be considered for future U.K. inertia platforms.

In face of the potentialities of the N.A.A. navigator and the results achieved it is not surprising that work on the much less successful FINE at M.I.T. has been terminated.

15.8 Cruise Control

The two distinct methods explored by M.I.T. for cruise control viz. computation of optimum from known aircraft data or determination of optimum during flight are noteworthy and have applications to other flight control problems, e.g. the manoeuvre computer for OR946.

15.9 Fuel Flow

Results obtained with the G.E.C. mass flow-meter are most impressive and it is strongly recommended that a sample be obtained (by direct purchase if necessary) for test in the U.K.

16 Acknowledgement

The authors are particular indebted to Wg. Cdr. A.H. Gibb of B.J.S.M., who accompanied them during most of their visit, for arranging an itinerary which made the most efficient use of the time available.

REFERENCES

No.	Author	Titles, etc.
1	-	Flight Instrument System for Fighters OR946
2	-	Programme for development of integrated presentation of flight information ONR Pamphlet
3	-	Integrated Instrumentation for aircraft - Human Engineering Phase, Dec. 1954 Dunlap and Associates Inc.
4	-	The MX 1179 Airborne Interception Equipment BJSM Air Liaison Note 87
5	-	Lear all attitude. Flight Indicator and Two-gyro Master Flight Control
6	-	Integrated instrument system Sperry Drg. 5231-90472-C
7	-	New Sperry System eases Pilot's Job Aviation Week 10.1.55
8	-	Engineering Report on qualification tests of G.E. fuel flowmeter system for Boeing Spec. D10-1611F, March 1955 GEC Report DF54M1 - 186B

Attached:

Drgs. Nos. IN.30947-30948
" IN.32733-32734
" IN.30995

Appendix I

Detachable Abstract Cards

Advance Distribution:

M.O.S. (Air) Headquarters

DCA
DGTD(A)
PDQRD(A)
ADSR (Records)
D Air Nav.
ADRD Inst A
ADRD Inst B
RD Inst 2 (action copy)
TPA3/TIB 120

Government Departments

I.A.P. Department

Head of Department
" Inst. Div.
" FIS Section
Authors 3
TPI Section
File

Royal Aircraft Establishment

Director
DDRAE(E)
Library

APPENDIX I

Itinerary and Principal Contacts

April			
25 M	Bu Aer Washington	W. Lovejoy - O'Connor	
26 Tu to 28 Th	W.A.D.C. Dayton	R. Ittelson L. Senecal N. Lashever	Communication and Navigation Lab.
		D. Stockman G. Purcell Dr. Graefer	Flight Control Branch
		Maj. Svimonoff Capt. Wright Dr. Ritchie - Kearns	Control Synthesis Branch
29 F	N.A.D.C. Johnsville	Cmdr. P. Holt Dr. Trawick L. Guarino - Mayo - Greenland	Aeronautical Instrument Lab.
May			
2 M	N.A.A. Los Angeles	R.M. Osborn A.J. Grant F.C. Bell D.T. Kimball D.E. Findley	Assistant Chief Group Leader System Engineer Gyroscopes Lab. Engineer
3 Tu	Douglas Aircraft El Segundo	A. Mayo R. Gaskell - Nolan	
4 W	Hughes Culver City	G. Murphy Dr. S. Roscoe L.R. Chase L.J. Laden P. McDowell - Wolf - Logan	Cockpit research group " Sub-system group Radar Navigation Air data computer Display
6 F	Lear Grand Rapids	A.F. Haiduck H. Thiry -. Schoepple J. Kuipers	Vice President and Gen. Manager Project Engineer Flight Instrument Engineer " " "

/9 M

Technical Note No. I.A.P. 1050

<u>May</u>

9 M	Eclipse Pioneer Teterboro	R.C. Sylvander	Director of Engineering
		J. Bevins	Asst. " " "
		C. Villiers	European Licensing
		D. Hembrough	Foreign Sales
		S. Waldow	Stable Platform
		- Hurlburt	Gyroscopes
		- Hazen	Air Data Computer
10 Tu	Kearfott Clifton	D. Smith	Vice President Engineering & Sales
		H.R. Shuart	Asst. Director of Engineering
		P. Weissburg	
		A.W. Reikel	Sales Manager
11 W	Kollsman	V. Carbonara	President
		A. Binnie	Vice President
		Admiral Clyde Smith	Asst. to President
		J. Andresen	Air Data Computer
		Dr. H. Eckweiler	Celestial navigation
		D. Nichinson	Navigation Computers
		G. Spiller	Lighting
12 Th	Sperry Great Neck	R.L. Stamper	Aero Department
		A. Lane (for G.F. Fragola) G. Schleich E. Zeigler G. Iddings	Flight Instrument Engineering
16 M	G.E.C. West Lynn	Dr. I.F. Kinnard	Manager Meter and Inst. Dept.
		H.E. Trekell	" Aircraft Inst. Engineering
		M. Prince	Manager Measurements Laboratory
		W.H. Campbell	Manager Instrument Manufacture
		M. Wendt	Senior Engineer
		- Tomb	Manager Aircraft Inst. Sales
17 Tu	M.I.T. Cambridge	Dr. Y.T. Li	Supervisor, Cruise Control Project
		T.R. Parsons	Supervisor, Aerophysics Research Group
		H.L. Pastan	Project Leader
		A. Navoy	Asst. Project Leader
		M.A. Hoffman	Staff Engineer
		W.B. Bryant	" "

Wing Cdr. A.H. Gibb of B.J.S.M. accompanied us except on the visits to Lear, G.E.C. and M.I.T.

SECRET - DISCREET.

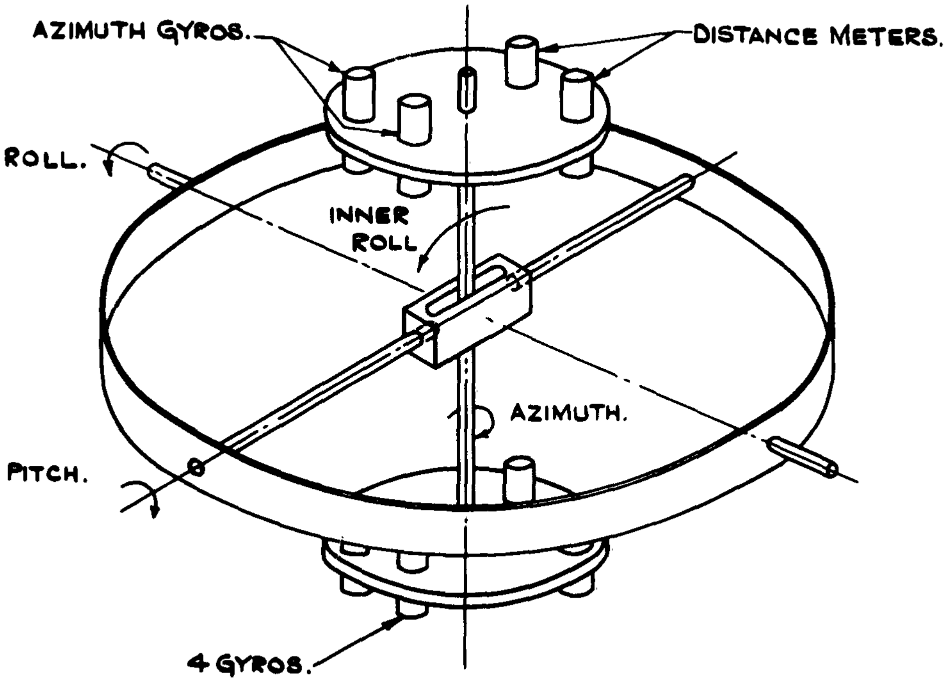


FIG. 1. N. A. A. GIMBAL SYSTEM. (DIAGRAMATIC)

SECRET – DISCREET.

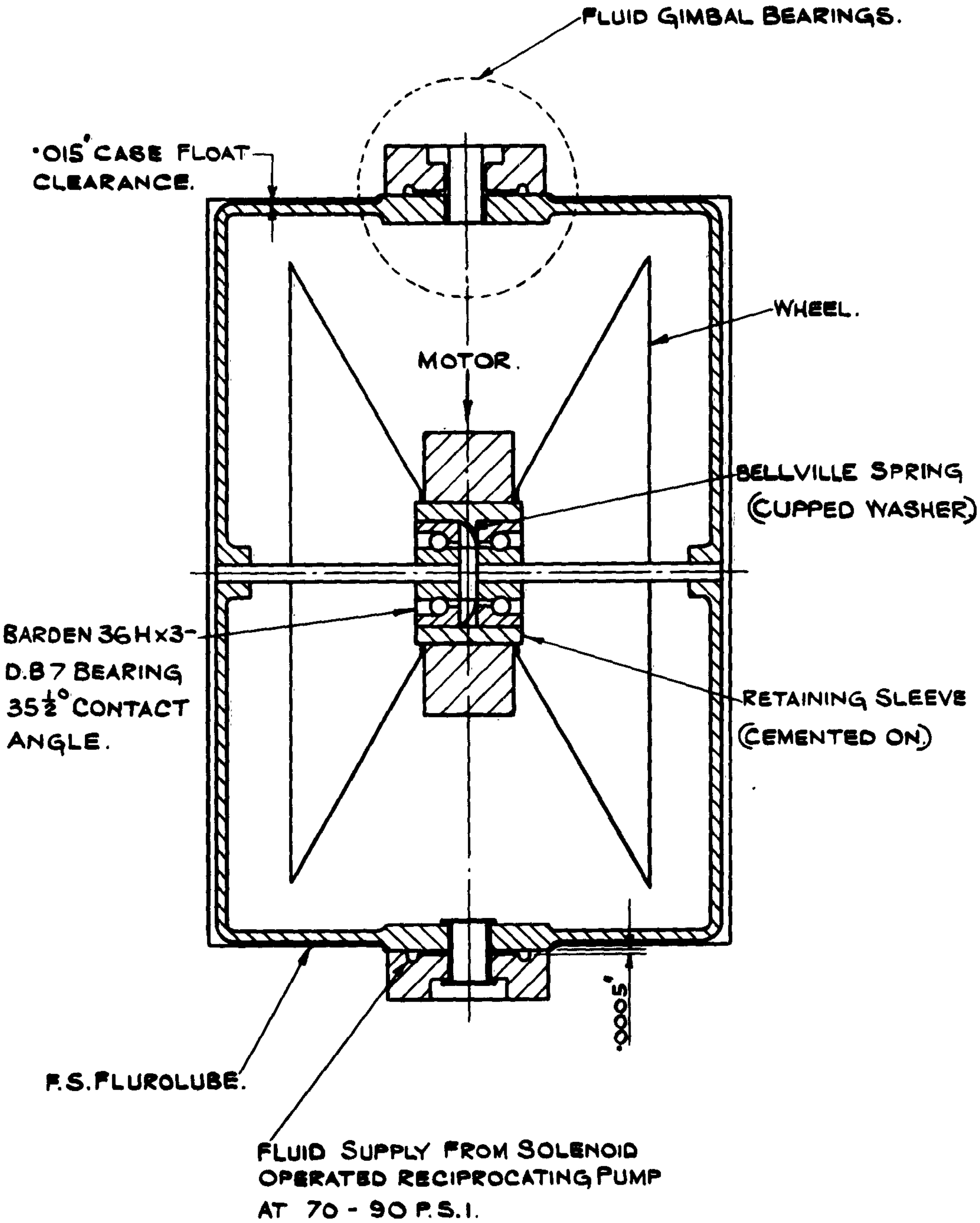
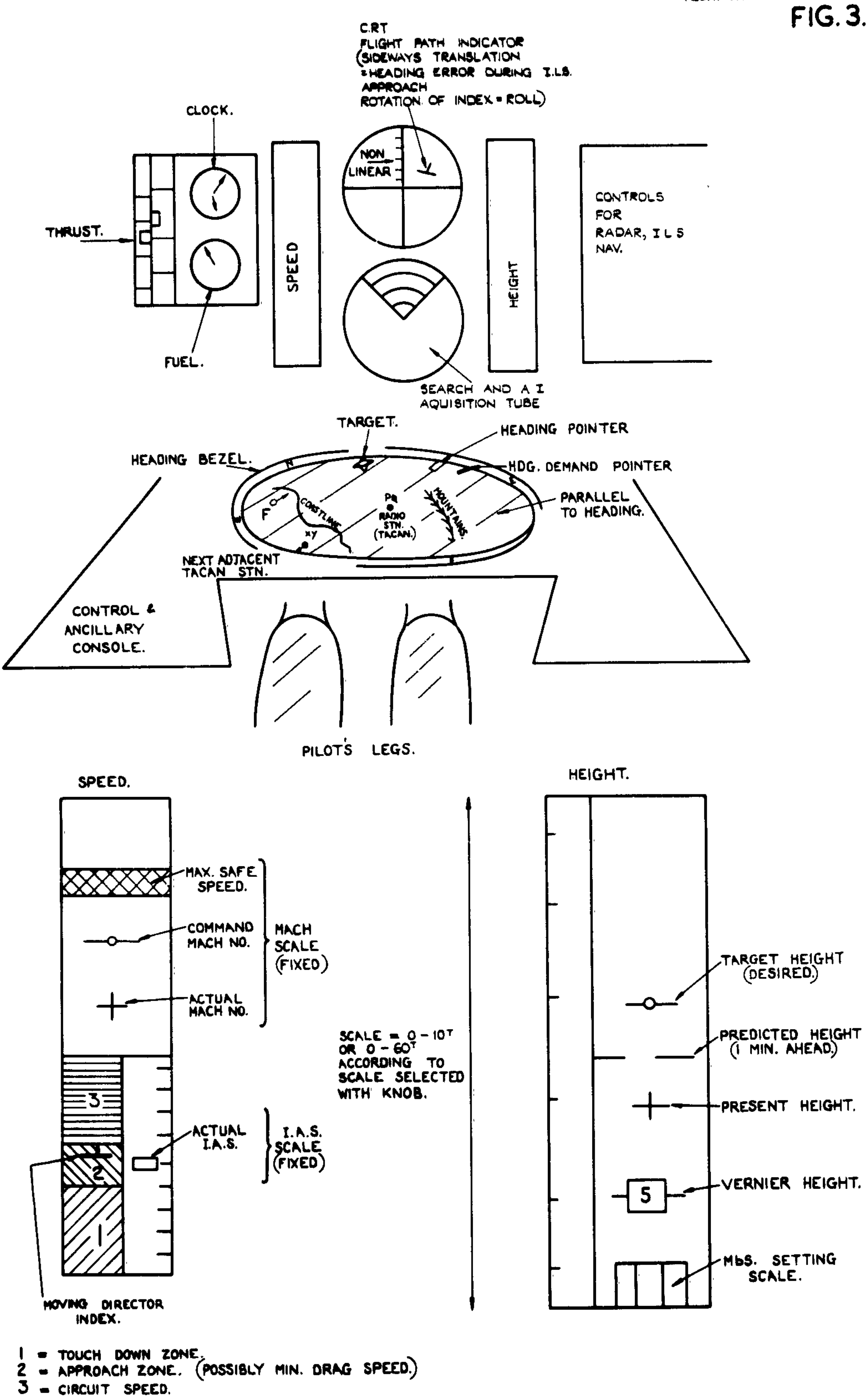


FIG. 2. N.A.A. G 5. GYRO.



1 = TOUCH DOWN ZONE.
2 = APPROACH ZONE. (POSSIBLY MIN. DRAG SPEED.)
3 = CIRCUIT SPEED.

FIG. 3. COCKPIT LAYOUT FOR MX 1179 SYSTEM.

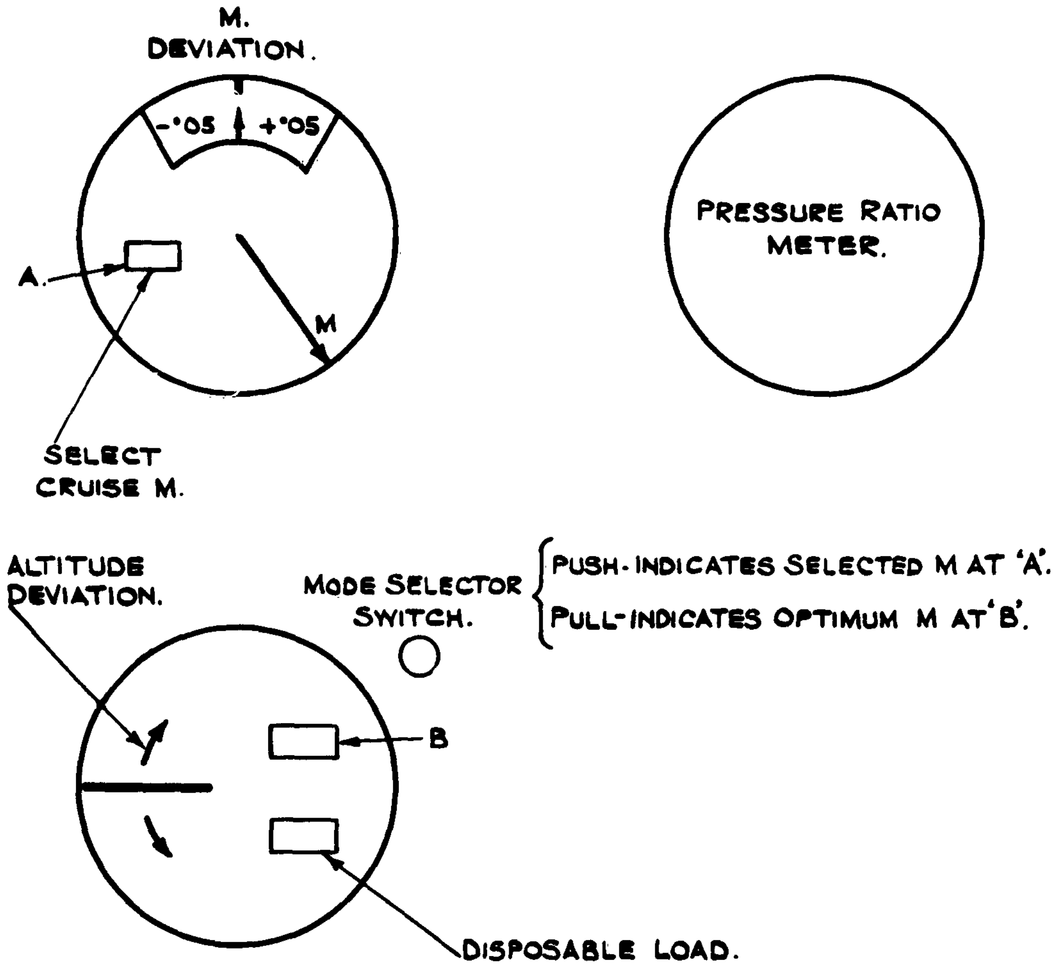


FIG. 4.
M.I.T. CRUISE CONTROL INSTRUMENTS.

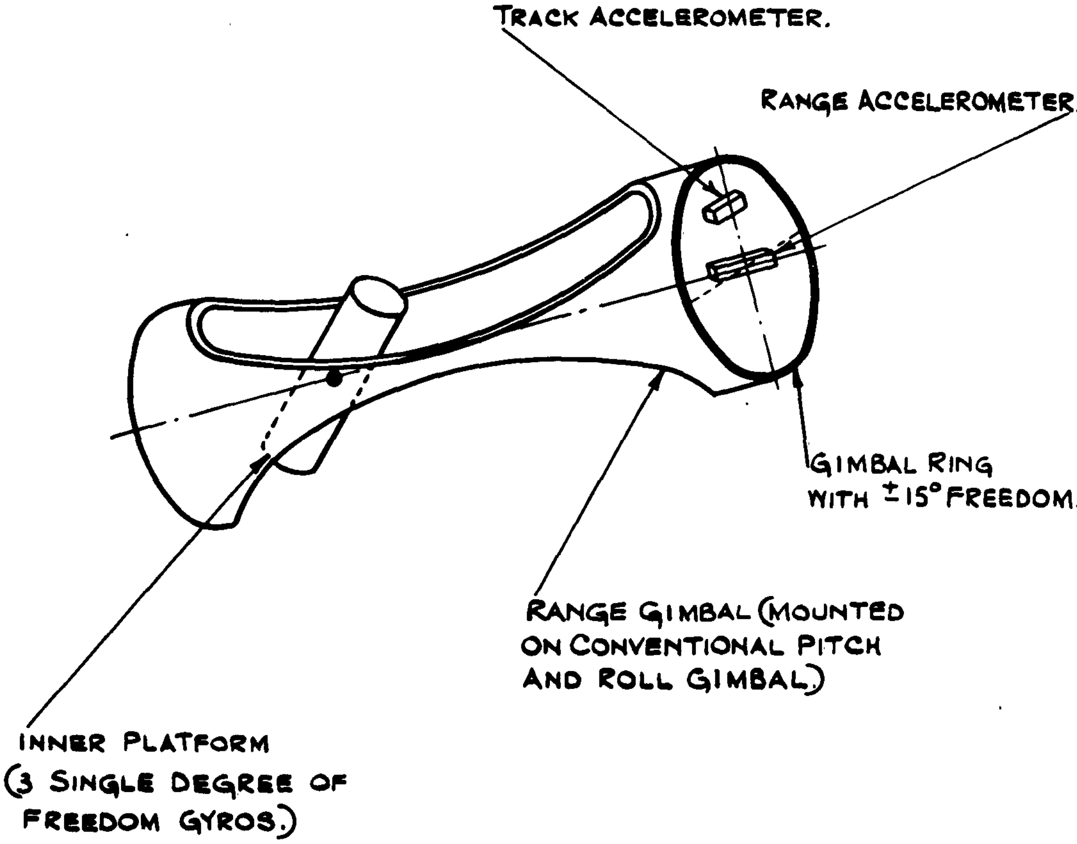


FIG. 5.
'BASKET' GIMBAL FOR SPIRE JUNIOR.

DETACHABLE ABSTRACT CARDS

These abstract cards are inserted in RAE Reports and Technical Notes for the convenience of Librarians and others who need to maintain an Information Index.

Detached cards are subject to the same Security Regulations as the parent document, and a record of their location should be made on the inside of the back cover of the parent document.

Secret-Discreet

Royal Aircraft Est. Technical Note No. I.A.P. 1050 — 06.076(73):
1955.9 — 629.1305
Jaques, C.N., Stratton, A., and Downey, S/Ldr. J.C.T.

FLIGHT INSTRUMENT SYSTEMS (Report on Visit to U.S.A.)

Information on the philosophy and development of flight instrument systems in the U.S.A. gained during a month's visit in April - May 1955 is recorded.

There is considerable emphasis on integrated weapon systems of which the instrument display and navigation systems are part; the system most advanced practically is the Hughes MX.1179.

While there is in the U.S.A. no 4-axis gimbal platform equivalent to the MRG(A), there are 5 independent developments aimed at defining the vertical to 0.2°, i.e. with an accuracy intermediate between the MRG(A) and an inertia navigator.

P.T.O.

SECRET-DISCREET

SECRET-DISCREET

Royal Aircraft Est. Technical Note No. I.A.P. 1050 — 06.076(73):
1955.9 — 629.1305
Jaques, C.N., Stratton, A., and Downey, S/Ldr. J.C.T.

FLIGHT INSTRUMENT SYSTEMS (Report on Visit to U.S.A.)

Information on the philosophy and development of flight instrument systems in the U.S.A. gained during a month's visit in April - May 1955 is recorded.

There is considerable emphasis on integrated weapon systems of which the instrument display and navigation systems are part; the system most advanced practically is the Hughes MX.1179.

While there is in the U.S.A. no 4-axis gimbal platform equivalent to the MRG(A), there are 5 independent developments aimed at defining the vertical to 0.2°, i.e. with an accuracy intermediate between the MRG(A) and an inertia navigator.

P.T.O.

SECRET-DISCREET

SECRET-DISCREET

Royal Aircraft Est. Technical Note No. I.A.P. 1050 — 06.076(73):
1955.9 — 629.1305
Jaques, C.N., Stratton, A., and Downey, S/Ldr. J.C.T.

FLIGHT INSTRUMENT SYSTEMS (Report on Visit to U.S.A.)

Information on the philosophy and development of flight instrument systems in the U.S.A. gained during a month's visit in April - May 1955 is recorded.

There is considerable emphasis on integrated weapon systems of which the instrument display and navigation systems are part; the system most advanced practically is the Hughes MX.1179.

While there is in the U.S.A. no 4-axis gimbal platform equivalent to the MRG(A), there are 5 independent developments aimed at defining the vertical to 0.2°, i.e. with an accuracy intermediate between the MRG(A) and an inertia navigator.

P.T.O.

SECRET-DISCREET

SECRET-DISCREET

Royal Aircraft Est. Technical Note No. I.A.P. 1050 — 06.076(73):
1955.9 — 629.1305
Jaques, C.N., Stratton, A., and Downey, S/Ldr. J.C.T.

FLIGHT INSTRUMENT SYSTEMS (Report on Visit to U.S.A.)

Information on the philosophy and development of flight instrument systems in the U.S.A. gained during a month's visit in April - May 1955 is recorded.

There is considerable emphasis on integrated weapon systems of which the instrument display and navigation systems are part; the system most advanced practically is the Hughes MX.1179.

While there is in the U.S.A. no 4-axis gimbal platform equivalent to the MRG(A), there are 5 independent developments aimed at defining the vertical to 0.2°, i.e. with an accuracy intermediate between the MRG(A) and an inertia navigator.

P.T.O.

SECRET-DISCREET

SECRET-DISCREET

Considerable attention is being paid to the possibility of displaying the tactical situation pictorially and to the use of CRT and optical methods of display. The U.S. places less emphasis than the U.K. on the problems of near vertical flight; the controversy between moving aeroplane and moving world in attitude presentation is still unresolved.

Some interesting and important work has been done on the problems of instrumentation for cruise control and engine handling.

The performance of the NAA Inertia Navigator under realistic conditions in an F86D is noteworthy.

SECRET-DISCREET

SECRET-DISCREET

Considerable attention is being paid to the possibility of displaying the tactical situation pictorially and to the use of CRT and optical methods of display. The U.S. places less emphasis than the U.K. on the problems of near vertical flight; the controversy between moving aeroplane and moving world in attitude presentation is still unresolved.

Some interesting and important work has been done on the problems of instrumentation for cruise control and engine handling.

The performance of the NAA Inertia Navigator under realistic conditions in an F86D is noteworthy.

SECRET-DISCREET

SECRET-DISCREET

Considerable attention is being paid to the possibility of displaying the tactical situation pictorially and to the use of CRT and optical methods of display. The U.S. places less emphasis than the U.K. on the problems of near vertical flight; the controversy between moving aeroplane and moving world in attitude presentation is still unresolved.

Some interesting and important work has been done on the problems of instrumentation for cruise control and engine handling.

The performance of the NAA Inertia Navigator under realistic conditions in an F86D is noteworthy.

SECRET-DISCREET

SECRET-DISCREET

Considerable attention is being paid to the possibility of displaying the tactical situation pictorially and to the use of CRT and optical methods of display. The U.S. places less emphasis than the U.K. on the problems of near vertical flight; the controversy between moving aeroplane and moving world in attitude presentation is still unresolved.

Some interesting and important work has been done on the problems of instrumentation for cruise control and engine handling.

The performance of the NAA Inertia Navigator under realistic conditions in an F86D is noteworthy.

SECRET-DISCREET

Information Centre
Knowledge Services
[dstl] *Porton Down,*
Salisbury
Wilts
SP4 0JQ
22060-6218
Tel 01980-613753
Fax 01980-613970

Defense Technical Information Center (DTIC)
8725 John J. Kingman Road, Suit 0944
Fort Belvoir, VA 22060-6218
U.S.A.

AD#: AD091912

Date of Search: 30 July 2008

Record Summary: AVIA 6/19060
Title: Flight instrument systems: report on visit to USA
Availability Open Document, Open Description, Normal Closure before FOI Act: 30 years
Former reference (Department) TECH NOTE IAP 1050
Held by The National Archives, Kew

This document is now available at the National Archives, Kew, Surrey, United Kingdom.

DTIC has checked the National Archives Catalogue website (http://www.nationalarchives.gov.uk) and found the document is available and releasable to the public.

Access to UK public records is governed by statute, namely the Public Records Act, 1958, and the Public Records Act, 1967.
The document has been released under the 30 year rule.
(The vast majority of records selected for permanent preservation are made available to the public when they are 30 years old. This is commonly referred to as the 30 year rule and was established by the Public Records Act of 1967).

This document may be treated as UNLIMITED.